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Development of a Compact Angle Resolving Spin Polarized Photoemission Spectrometer for "Double Polarization" X-Ray Photoelectron Diffraction Spectroscopy of Magnetic Nanostructures.

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X-ray Photoelectron Diffraction (XPD) is a well established technique for probing element and site specific surface structure of epitaxial thin films and nanostructures. Furthermore, recent studies have demonstrated that excitation of the photoelectrons via circularly polarized photons results in additional sensitivity to the element and site specific local magnetic order via the dipole selection rules[1]. However the asymmetries involved in such experiments are very low, typically 1-2%. Calculations suggest that combining excitation via circularly polarized photons with spin polarized photoelectron detection into a complete "double polarization" experiment should lead to a 5-10 fold increase in asymmetry[2]. However combining high angular resolution XPD with spin resolving capability poses significant experimental challenges.

A new compact angle resolving spin spectrometer for conducting such double polarization experiments has recently been developed at the Advanced Light Source by the authors. This spectrometer combines a large (11 inch) diameter fixed hemispherical analyzer with a novel rotatable input lens system allowing data with +-1 degree angular resolution to be acquired for any combination of incident and emission angles, including normal incidence / normal emission (figure 1). The analyzer is equipped with both multichannel detection for high resolution (50meV) spin integrated spectroscopies, such as XPS and magnetic linear or circular dichroism, and a Mott detector capable of resolving the photoelectron spin polarization simultaneously along the two perpendicular axes of the rotational plane. Rapid switching between spin integrated and spin resolved modes is achieved by focusing the photoelectrons through a small hole in the detector of the hemispherical analyzer and into a compact mini-Mott detector situated immediately behind the channelplates.

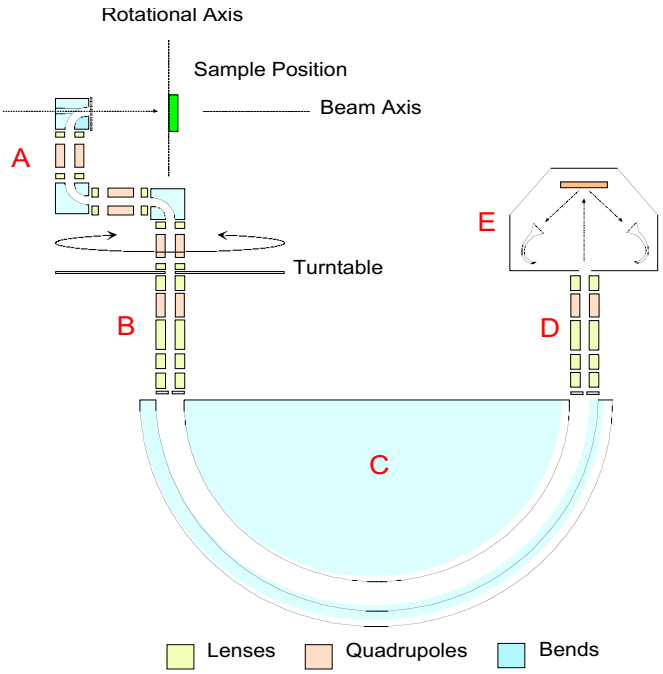


Figure 1.

Schematic of the analyzer and lens assembly.

A. Rotating entrance lens assembly
B. Transfer lenses
C. Fixed Large diameter hemispherical analyzer
D. Transfer lenses
E. Fixed spin resolving Mott detector

This combination of fixed hemispherical analyser and in-situ rotating lens assembly results in a number of key advantages over possible alternative spectrometer designs. Whilst the input lens assembly is able to collect photoelectrons from any emission angle the measurement axes of the Mott detector remain fixed along, and perpendicular to, the beam axis. This considerably simplifies the analytical interpretation of angular spin polarization data. Furthermore the complete elimination of the large differentially pumped rotary feedthroughs that are normally required for such large diameter rotating analyzer systems results in a much more compact spectrometer design. Indeed, the positioning of the analyzer beneath the chamber results in a spectrometer footprint that is smaller than most conventional XPS systems (figure 2). In addition, the small, in-situ lens assembly causes minimal obstruction of the area around the sample without compromising the overall resolution; as would be the case with a conventional small, ARPES style, in-situ rotating hemispherical analyzer. The addition of a small hole through the first bending element also allows for normal incidence / normal emission experiments to be conducted; a high symmetry geometry that is important for verification of certain theoretical models.

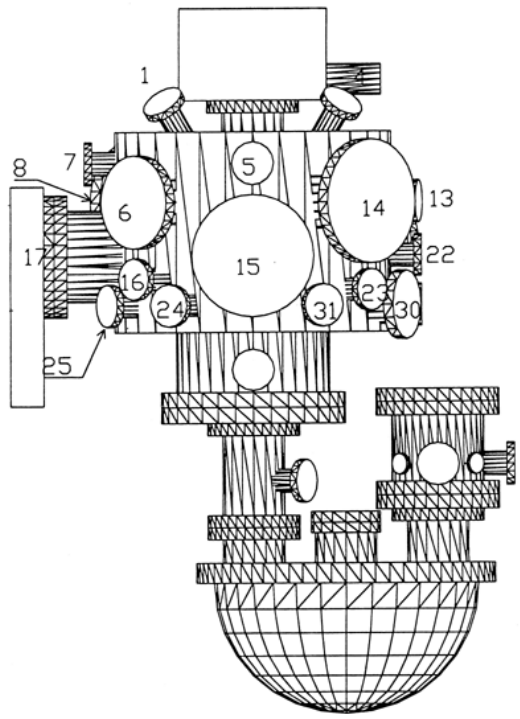
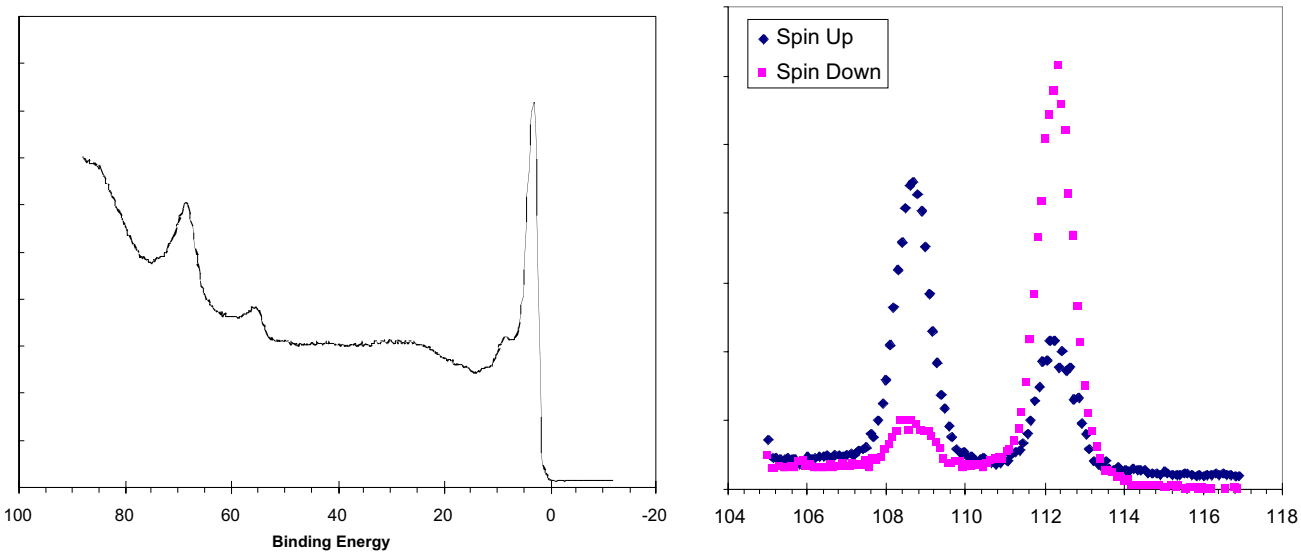


Figure 2.

Schematic of the analyzer system mounted beneath the analysis chamber. The resulting instrumental footprint is smaller than most conventional XPS systems.

Commissioning of this spectrometer is now almost complete and analyzer performance has been successfully verified across all important operational modes including spin integrated XPS, UPS (figure 3a), photon energy dependent UPS, ARPES, spin resolved photoemission and double polarization photoemission (figure 3b) using a wide variety of magnetic and non-magnetic materials. Furthermore, in addition to the described analyzer, the spectrometer system also provides a wide range of complementary sample preparation and analytical tools including in-situ MBE growth facilities, LEED IV-Auger and dual anode X-ray excitation source for complete characterization of *in-situ* and *ex-situ* prepared magnetic nano-structures.



(a) (b)

Figure 3.

Sample spectra from the new analyzer taken in two different data acquisition modes

(a) Valence band UPS spectrum of 12ML $Fe_{40}Ni_60$ epitaxial thin film on Cu(100)
(b) "Double Polarization" spectrum of Au(111) 4f peak.
Note that the combination of circularly polarized excitation with spin polarized detection can be used to produce spin polarized data from non-magnetic samples.

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